DIFFERENCE IN THE OSSIFICATION OF THE MALE AND FEMALE SKELETON

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Shortly after the announcement of the discovery of X-rays in 1895, I thought I saw an opportunity of using this method in a research, corroborating or correcting the time element in commencing ossification as given in the standard works of anatomy. It was not, however, until 1905 that I had collected sufficient data on which to base an opinion. I then published a brief account of my findings. This method seemed to me to be the only one in which a large number of subjects could be obtained, and the average time at which the centres of ossification were making their appearance determined with accuracy. In using living material for this examination a subject of desired age could be selected and could be subsequently re-examined for months, or even years as the results indicated. The rate of growth could thus be determined while in other subjects the times of appearance of centres of ossification could be estimated with reasonable accuracy. I understood that the older method of microscopic observations with serial sections would necessarily be very limited. The specimens had to be obtained from the dead house, and the labour involved would preclude the examination of large numbers and the data could not be as accurate as those obtained from the living subject.

In 1906, the date of my second publication, I felt justified in announcing the following conclusions:

First. The process of ossification is inaugurated much sooner than has hitherto been supposed.

Second. The bones of the female ossify in advance of those of the male. This advance may be measured in early stages by days, later by months, and subsequently by years.

Third. The chronological order of ossification of the bones of the carpus is different from that formerly supposed.

Fourth. The bones of a first child ossify, as a rule, sooner than those of subsequent children.

Fifth. Ossification is bilaterally symmetrical regardless of variations (normal) which may occur.

Sixth. The union of the epiphyses with the diaphyses takes place much sooner than was formerly supposed.

Seventh. Variation in the ossification of bones is a heritable trait. The

difference in ossification of the male and female skeleton may be grouped as follows:

First, a comparison of the time of appearance of centres of ossification.

Second, the time of the union of the epiphyses with the diaphyses.

Third, there may be differences in chronological order of ossification.

In regard to the first two groups I can give abundant proof.

I have given very little attention to the third group and will refer to it in brief only.

My conclusions are based upon the study of nine hundred and ninety-four Roentgenograms of which one hundred and forty are foetuses between the ages of ten and a half weeks and thirty-eight weeks; one hundred new-born babes between the ages of one hour and seven days; five hundred and fifty-four children between the age of three months and twelve years and two hundred from twelve years to twenty-three years of age. From an examination of the five hundred and fifty-four hands of children, noting the size of the centres of ossification in mm. of the bones of the carpus, there was abundant evidence that the bones of the female are much in advance of those of the male and I estimated the time of appearance of these centres as follows:

CARPUS

1. *Capitatum.*
   Female: between the third and sixth month.
   Male: between the fourth and tenth month.
2. *Hamatum.*
   Female: between the fifth and tenth month.
   Male: between the sixth and twelfth month.
3. *Triquetrum.*
   Female: between the second and third year.
   Male: about three years of age.
4. *Lunatum.*
   Female: between the third and fourth year.
   Male: about four years of age.
5. *Navicular.*
   Female: at four years of age or early in fifth year.
   Male: about five years of age.
6. Lesser *Multangular.*
   Female: between the fourth and fifth year (preceding the greater multangular).
   Male: between the fifth and sixth year (preceding the greater multangular).
7. Greater *Multangular.*
   Female: between the fourth and fifth year (preceded by the lesser multangular).
   Male: between the fifth and sixth year (preceded by the lesser multangular).

8. *Pisiform.*
   Female: between the ninth and tenth year.
   Male: between the twelfth and thirteenth year.

A table giving the name, sex, age, and size in mm. of these centres has been published, and I will only explain and describe a few, sufficient, however, to demonstrate the differences between the two sexes. Fig. 1 illustrates a case in which ossification is much in advance of the average. In this hand of a girl, age one year, two months and twenty days, it was known that ossification of the capitatum and hamatum had commenced several weeks before birth and

Fig. 1.

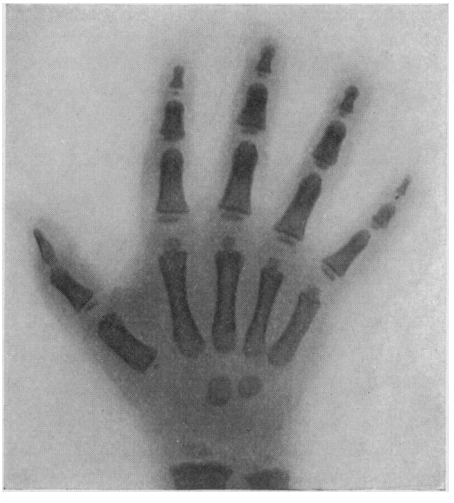

Fig. 2.

Fig. 1. Female, age one year, two months, twenty days. The capitatum and hamatum began to ossify several weeks before birth, and the triquetrum when about eight months of age.
A number of the epiphyses had commenced ossification before the close of the first year, some of them as early as the eighth month. The epiphysis of the radius at birth or shortly after birth (reduced $\frac{2}{3}$).

Fig. 2. Female, age one year and nine months. The capitatum and hamatum began to ossify before birth. The epiphysis of the radius soon after birth and many of the epiphyses of the metacarpal bones and the phalanges before the close of the first year (reduced $\frac{1}{2}$).

that of the triquetrum when about eight months of age. A number of the epiphyses had commenced to ossify before the close of the first year, some of these as early as the eighth month. The epiphysis of the radius must have been present at birth. While this hand is in advance of the average, it is not a rare exception, as is shown by fig. 2 which represents the hand of a girl of twenty-one months and shows a condition of ossification much in advance of any male of corresponding age that I have seen. I could quote a large

number of similar cases, but space will not permit. Figs. 3 *A* and 3 *B* illustrate the hand of a male of eight months of age and that of a female eight months old respectively. In the male hand there is a small centre of ossification in the hamatum while in the female there are large centres in the capitatum and hamatum. In the female ossification in the two bones began before birth; in the capitatum about the thirty-eighth week of intra-uterine life. Fig. 4 illustrates the hand of a female five years of age. This is an example of the erratic course sometimes found in the chronological order of ossification of the bones of the carpus. It is to be noted that the lesser multangular is in the fourth position in order of ossification. I have found it in this position nine times out of one hundred and six cases. It is also to be noted that the greater multangular occupies the fifth position. I have found this bone occupying the fourth position in seven only out of one hundred and six cases. The navicular is in the sixth position and the lunatum in the seventh. I have found the lunatum occupying this position in six out of one hundred and eighty-six instances, and they were all females. I would suggest that this fact may be of some significance.

The usual chronological order is as follows: (1) the capitatum, (2) the hamatum, (3) the triquetrum, (4) the lunatum, (5) the navicular, (6) the lesser multangular, (7) the greater multangular and (8) the pisiform. In two hundred and twenty-nine subjects the capitatum occupied the first position in two hundred and twenty-five cases, and the second position in four cases only. The hamatum was four times in the first position and two hundred and twenty-five times in the second. The triquetrum is in the third position in which it was found in two hundred and eleven cases, and in the fourth position in ten cases. It is never displaced from this, its normal position, by other bones except by the lunatum. The position of the lunatum is fourth and it was thus found in one hundred and fifty-eight out of one hundred and eighty-six cases. The navicular occupies the fifth position in which it was found in sixty-eight out of one hundred and eleven cases. The lesser multangular occupies the sixth position in which it was found forty-seven times in one hundred and six instances. The position of the greater multangular is seventh, a position in which it was found in forty out of one hundred and six instances. The pisiform is the last bone to ossify and consequently occupies the eighth position. I have explained this at some length for the reason that the correct order of ossification has not yet found its way into textbooks of anatomy. The difference of ossification in male and female was shown in a very spectacular way by the examination of twins of the same sex (female) and of twins of opposite sex. In the former the ossification of the carpus of the two girls seven years of age was identical. In the latter, a boy and a girl five years of age, the difference in ossification is very pronounced. In the girl's hand three bones, viz. the navicular, the greater and the lesser multangular, had all very definite nodules of ossification while the three corresponding bones in the boy's carpus showed no indication of ossification whatever. The limits of this

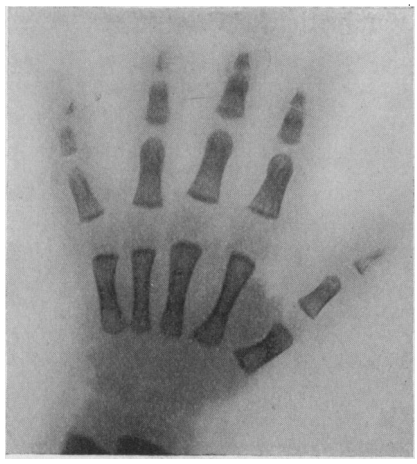

Fig. 3 *A*.

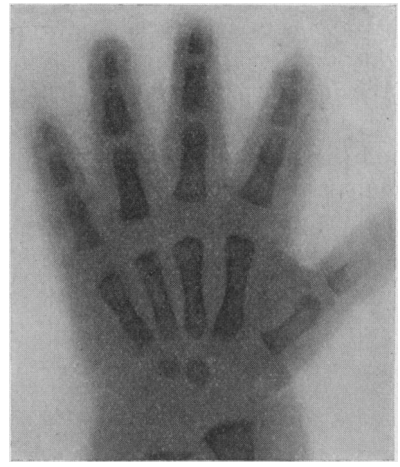

Fig. 3 *B*.

Fig. 3 *A*. Male, age eight months. The hamatum shows a small centre of ossification.
Fig. 3 *B*. Female, age eight months. The capitatum and hamatum began ossification before birth.

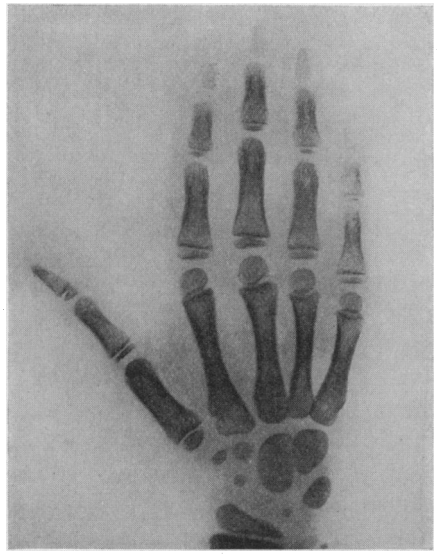

Fig. 4. Female, age five years, one month. The chronological order of ossification of the carpus is unusual and is as follows: the capitatum, hamatum, triquetrum, lesser multangular, greater multangular, navicular and lunatum, which last bone is in the seventh position, its usual position being fourth.

paper will not permit me to dwell upon the union of the epiphyses with the diaphyses. In my last paper published in the *American Journal of Physical Anthropology*, I gave the results of the examination of sixty-four male and eighty-one female hands. In the female hand complete union of the epiphyses of the metacarpal bones and of the phalanges was found at sixteen years of age. I have found them united at fourteen years and three months in the female hand (fig. 5), while the earliest case in which these epiphyses were united in the male hand was in one of the age of seventeen years and four months. In some instances I have found them united in the male hand between eighteen and nineteen, but in most cases it is not completed in male hands until between

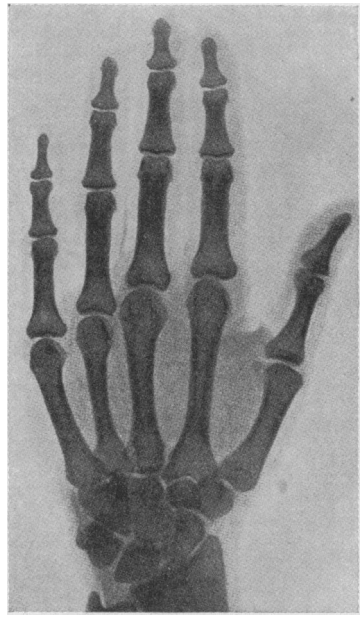

Fig. 5. Female, age fourteen years, three months. All of the epiphyses of the metacarpal bones and the phalanges have united with the shafts.

nineteen and twenty years of age. It will thus be seen there is a difference of three years between the two sexes. I think this is an anatomical fact of surgical importance and should be known and recognised. I have reserved consideration of embryos and of the new-born babe for the latter part of this paper.

I have not been able to study a sufficient number of cleared embryos to make positive statements as to the appearance of the earliest centres of ossification.

Unfortunately with the cleared embryos I have examined, the sex was not noted before the clearing process, and as regards older embryos in which the external genitalia could be distinguished, I have examined a few specimens

only. In a fifty-two mm. female embryo, age ten and a half weeks (fig. 6, 1), a large centre of ossification in the ilium and a small centre in the ischium are apparent. This condition is to be compared with that of a sixty-two mm.

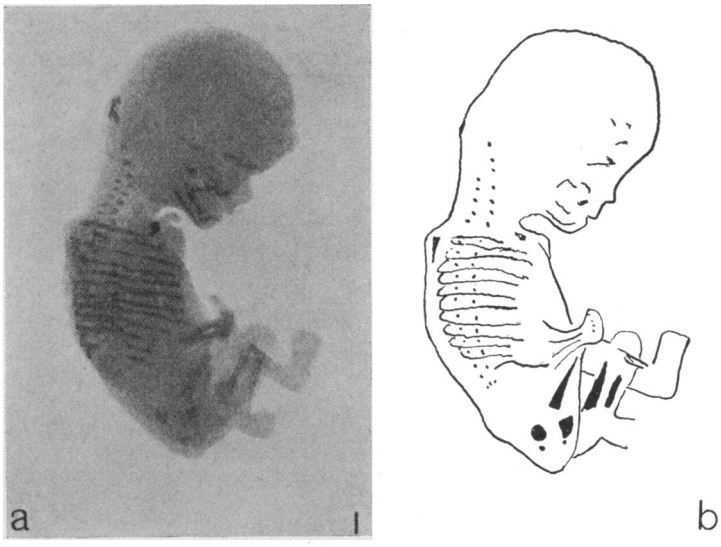

Fig. 6, 1. Embryo 52 mm. female.

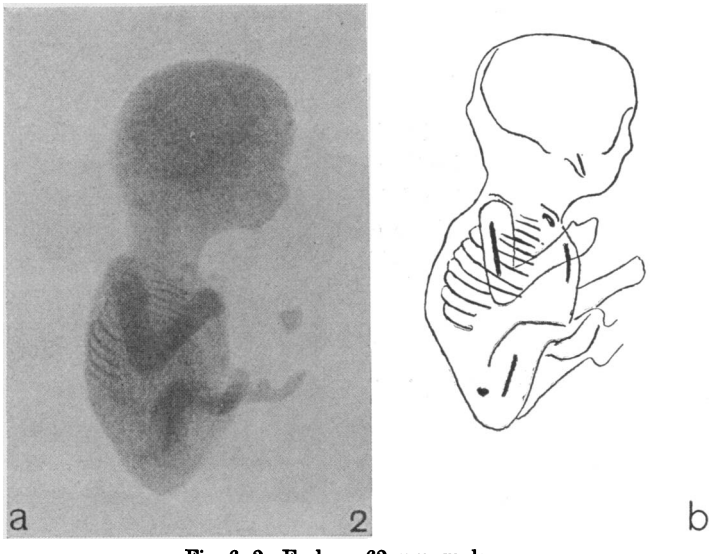

Fig. 6, 2. Embryo 62 mm. male.

male embryo, age eleven weeks (fig. 6, 2), in which there is a very small centre in the ilium and none in the ischium. In the female there are a large number of centres in the vertebrae while very few if any are to be seen in the male

embryo. In the study of one hundred new-born babes there is abundant proof of the difference between the two sexes. The parts observed were the carpus, the tarsus, the epiphyses at the distal extremity of the femur and at the proximal extremity of the tibia. In the paper published on this subject the size in mm. of these centres was given and comparisons made.

I will discuss two of these, the most advanced female and the most advanced male. In the male hand a minute centre of ossification in the capitatum and medium-sized centres in the epiphyses of the femur and of the tibia and somewhat larger centres in the calcaneus and talus were present. In the female hand centres of ossification were present in the capitatum and hamatum several weeks before birth and the epiphyses of the femur and tibia were quite large. Large centres of ossification were present in the calcaneus and talus and all of these were at least double the size of those seen in the male. A large centre, not present in the male, was to be seen in the cuboid. I have been asked a number of times if it would be possible by this method to determine the sex of the foetus *in utero*. Undoubtedly it would be possible in some instances provided one could produce a Roentgenogram showing what is to be seen in an isolated embryo. Had a Roentgenogram been made at the thirty-second week of intra-uterine life all of the centres mentioned above except those of the carpus might have been present and had this been the case one could have said positively that it was a female. However, in my experience, it is impossible to make these Roentgenograms. I have made a number of Roentgenograms of the foetus *in utero* in which the entire skeleton could be well seen, especially the skull, the vertebral column, the ribs and all the long bones, but the epiphyses could not be seen. Even if it were possible to make these Roentgenograms I do not see any practical value in the determination of sex before birth; but from a medico-legal point of view the determination of sex after birth by means of an examination of the bones of the skeleton is of the greatest importance. With the data I have at hand groupings of these could be made, or the absence of these centres shown, by means of which the sex, in a large percentage of cases, could be identified. Of course slow ossification in both sexes and rapid ossification in both sexes making exceptions to the rule are met with. With a more comprehensive study of the subject and additional data, I think groupings could be made whereby identification of the sex of the skeleton could, within reasonable limits, be made possible.